Journal of Energy Technologies and Policy www.iiste.org
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.3, No.11, 2013 – Special Issue for International Conference on Energy, Environment and Sustainable Economy (EESE 2013)

Sun as a clean energy source for lighting buildings Case Study: Daylighting Design in Tehran (Iran)

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Abstract

By reducing the need for electric light, daylighting can substantially lower home energy use. However, excessive daylighting can increase both heating and cooling loads. A balanced approach to daylighting involves whole building design starting with the location and orientation of a home and continuing with proper room location and design, window sizing and placement, and selection of room finishes.

This study has shown that daylight factor is insensitive to both the prevailing climate and building orientation. The drive towards sustainable, low-energy buildings places increasing emphasis on detailed performance evaluation at the early design stage. Recent advances in lighting simulation techniques have demonstrated that reliable predictions founded on hourly climatic data are attainable. This paper describes the application of climate-based daylight modelling to Tehran's buildins.

Keywards: daylight factor, Climatic design, Tehran

1. Introduction

1.1 Introduce the Problem

Daylighting is the art and science of using natural light to illuminate indoor spaces. It saves energy, and can make living and working areas more attractive and comfortable. Daylighting in homes is typically accomplished using windows, translucent doors, skylights, light pipes (tubular skylights), and clerestories. A well designed daylight home on a sunny lot can get by without any electric lighting between dawn and dusk (ASHRAE/IESNA 90.1 Standard, 2004). Daylight is sunlight that is direct or reflected. Sunshine provides us with vitamin D, and also combats seasonal affective disorder, or winter depression. Natural light doesn't change the character of colors the way artificial lights can and, with its subtly changing intensity, daylight is much more interesting. It can make us feel more connected to nature and supports our natural biological rhythms, which contribute to restful sleep. Using sunlight in your home can decrease heating and cooling loads through passive solar design techniques, as well as eliminate most lighting needs during the day. Its use has been proven, in commercial settings and schools, to decrease absenteeism and increase productivity and test scores. Also, people who work in naturally lit buildings report a sense of well-being (Mardaljevic, 2002).

Also daylighting is the use of natural light to reduce artificial lighting in buildings (Bodart&et all, 2006). Artificial lighting accounts for up to 30% of the energy usage of typical office buildings. If you include the additional cooling required by heat generated by artificial lights, the total energy usage caused by artificial lighting could approach 50%. Using daylight to reduce the usage of artificial lighting can greatly increase the energy efficiency of buildings.This article will illustrate how Architects can use free and readily available tools to integrate daylighting into their building design.

2. Method

Daylighting requires illumination from exterior environment. The first step is to determine the light levels outside the building. Daylight comes from not just direct sunlight but also from illumination from the sky on overcast days (Farley, 2004). Design Sky illuminance levels in different latitudes. Using the calculator on Autodesk Ecotect's website, we can also determine the recommended Lux levels for particular latitude. The Design Sky illuminance levels "represent the horizontal illuminance value that is exceeded 85% of the time between the hours of 9am and 5pm throughout the working year. Thus they also represent a worst-case scenario that you can design to and are sure your building will meet the desired light levels at least 85% of the time.

EESE-2013 is organised by International Society for Commerce, Industry & Engineering.

Table 1. Daylight factor (DF) calculation

DF	E_{in}	E_{ext}
2.5%	250 Lux	10000 Lux

DF	APPEARANCE	ENERGY IMPLICATIONS
< 2%	room looks gloomy	Electric lighting needed most of the day
2% to 5%	**Predominantly daylit appearance**	**Good balance between lighting and thermal aspects**
> 5%	Room appears stongly daylit	potential for thermal problems due to overheating in summer and heat

$DF = 100 * E_{in} / E_{ext}$
DF Daylight Factor
E_{in} Interiior Illuminance (250 Lux)
E_{ext} Exterior Illuminance

Once the outside light level is determined, we can calculate the Daylight Factor to determine the feasibility of using daylighting in our design. Daylight Factor is a ratio of outside illuminance over inside illuminance (Mardaljevic, 2004). The Design Sky Illuminance Calculating for Tehran tells us that the outside illuminance at latitude 35.7 is 10000 Lux. The design interior ambient light level for office activity is 250 Lux (Hattrup, 1990). Table 1 tells us at the Daylight Factor (DF) for this scenario is 2.5%. 2.5% is within the acceptable range for daylit spaces. DF under 2% will feel gloomy, and DF over 5% could result in a design that is over-glazed, resulting in too much heat gain or heat lost.

Table 2. Glazing factor (GF) calculation

	GLAZING FACTOR	FLOOR AREA	WINDOW AREA	TVIS
DAYLIGHT	0.66%	9600 S.F	450 S.F.	0.7
VISION	1.88%	9600 S.F	2100 S.F.	0.5
TOTAL	**2.53%**			

$$\text{GLAZING FACTOR (GF)} = \frac{\text{WINDOW AREA}}{\text{FLOOR AREA}} * \text{GEOMETRY FACTOR} * \frac{\text{ACTUAL TVIS}}{\text{MIN. TVIS}} * \text{HEIGHT FACTOR} \quad (1)$$

(LEED EQ Credit 8.1 requires 75% of space to have GF over 2%)(3)

The Glazing Factor (GF) Calculation (LEED version 2.2) is also a ratio of interior illuminance to exterior illuminance under overcast sky conditions. Unlike the basic Daylight Factor calculation, the Glazing Factor takes into account the window and skylight size and configuration in its calculation (Inoue& et all, 1988). Table 2 illustrates a hypothetical building with 5' high vision windows and 18" daylight windows on the North and South elevations. On the East and West elevations, 5' high vision windows cover 50% of the facade. Our hypothetical building achieves a Glazing Factor of 2.53%. These simple calculations show that daylighting can be employed without greatly compromising the comfort and energy performance of the building.

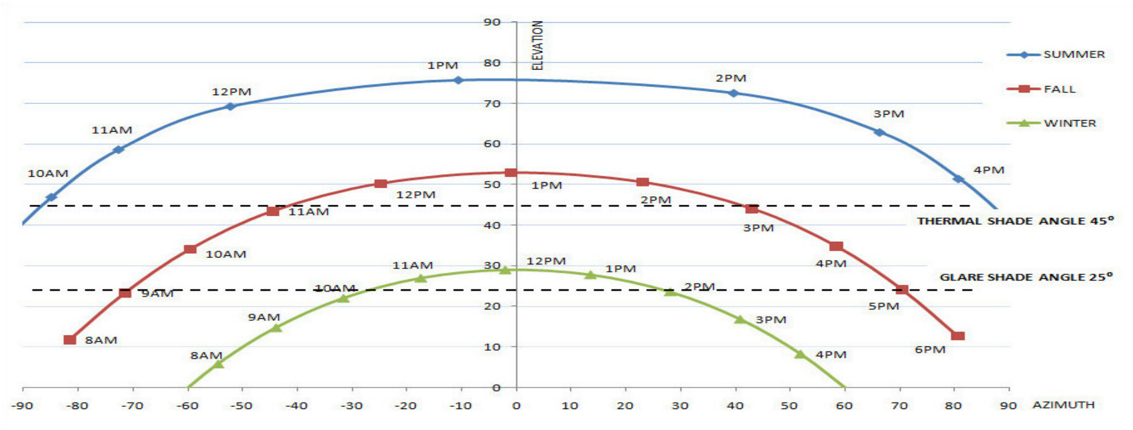
2.1SOLAR SHADING TO CONTROL CLARE AND HAET GAIN

Daylight design involves more than providing useful illumination in the building. Often, it has to address the negative side effects of natural light: glare and heat gain/loss. Glare comes from excessive contrast that usually results from direct beam sunlight striking interior surfaces. Unwanted heat gain occurs when sunlight enters the building on warm days. The solution to glare and heat gain comes in some form of sun control strategy that employs sun shades, light shelves, blinds, or shade cloth.
The sun control strategy to use depends on climate and orientation of the facade. This article will study a building in the Iran (Tehran located in Latitude 35.7). At this latitude, the shading strategy can be summed up as follows:

- North Elevation: no shading required. Indirect sunlight makes this facade ideal for daylighting.

- East Elevation: low sun angles in the morning and no sun in the afternoon. Active shading devices, blinds, or shade cloths works best for glare control.
- West Elevation: no sun in the morning but low sun angles in the afternoon. Active shading devices, blinds, or shade cloths works best for glare control. Afternoon heat gain is a problem in this climate, it is best to reduce the size and amount of West facing windows.
- South Elevation: high sun angles most of the day makes this facade ideal for passive

Figure 2.Tehran sun path diagram



The most common passive shading strategy uses a combination of sunshade and light shelf. Figure 2 shows the path of the sun from outside South facing windows. We can use this diagram to optimize our shading strategy. There are two reasons for shading: reduce heat gain and eliminate glare. These two criteria are expressed as dashed lines in Figure 2. Each dashed line expresses an angle above which the sun will be shaded.

Thermal shading control heat gain in the summer and allow sunlight to warm the building in the winter. In Figure 2, the thermal shade angle is set at 45 degrees. In the summer, this angle will shade the window from 10am to 5pm. In the winter, this window will not be shaded at all. Solar thermal shading works best for sunshades above vision windows (windows between 2'-6" and 7'-6").Glare shading prevents direct sunlight from striking interior surfaces, creating excessive contrast. Figure 2 shows the glare shade angle at 25 degrees. At this angle, direct sunlight is shaded from 9am to 5pm in the spring, summer, and fall. In the winter, direct sunlight is shaded from 10am to 2pm. Glare shading is usually used to control glare on daylight (clerestory) windows, glazing above 7'-6". Daylight windows, when used in conjunction with light shelves to shield direct sunlight from the building perimeter, bounce light off the ceiling to light up the building interior.

The thermal shading line and glare shading line can be adjusted to meet the designer's criteria. We can balance the competing needs of more daylight and less glare/heat gain. Where the windows are not adequately shaded, users will usually deploy shade cloths to address thermal comfort and glare issues. Shade cloths, with 3-15% openness, usually filter out most of the useful daylight entering the building. Therefore, it is essential to design the sunshades and light shelves to optimize the amount of daylit hours to reduce the use of artificial lighting.

Figure 3. section of suneshade & life shelf

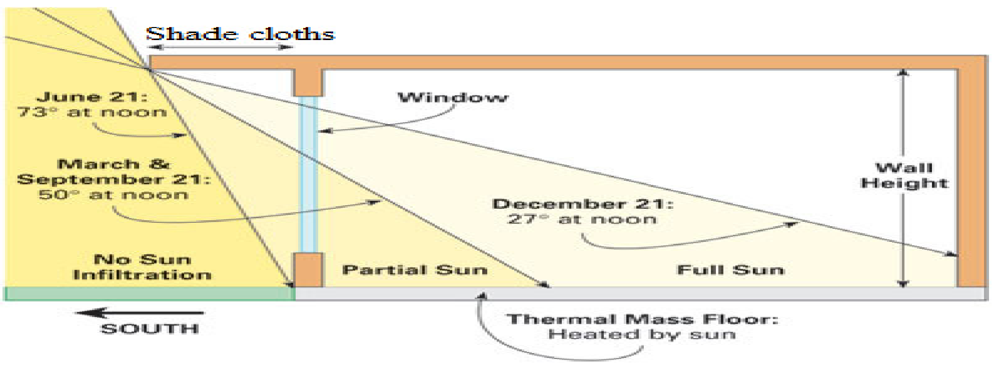
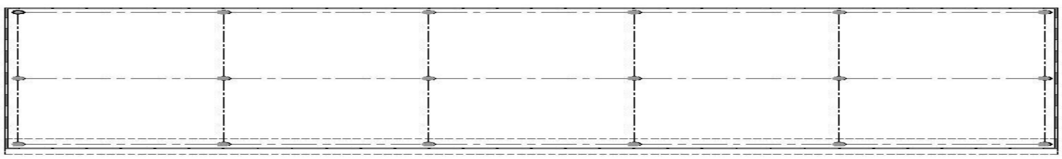


Figure 3 illustrates how the sunshade and light shelf could be designed to meet criteria set in Figure 2. Sun shades devices outside the building. In this illustration, the sunshade shields the vision window at a 45 degrees angle, keeping out heat gain and glares most of the day in summer and fall. Light shelves are inside buildings. They protect the building perimeter from direct sunlight and bounce light off the ceiling to light up the building interior. In this example, the light shelf is around 4 feet deep to prevent glare up to a 25 degree sun angle. As you can see from this illustration, the depth of the sunshade and light shelf can also be constrained by construction and code issues. Cantilevered sunshades require structural reinforcing to withstand wind uplift. Interior light shelves can obscure fire sprinkler distribution (Kendrick & Skinner, 1980).

2.2 DAYLIGHT MODELING

Computer software daylight modeling can be a very useful tool to analyze and optimize the daylighting design. any software programs are available; most are free to use (Lindelöf & Morel, 2006). The most commonly used software is the Unix-based Radiance Sythethic Imaging System developed by Lawrence Berkeley National Laboratory. Radiance is reputed to by very accurate; however, it is not easy to use. The simulation in this study was done using DIALux, professional lighting design software widely used in Europe.

Figure 4. Floor plan



This study assumes a 70' wide rectangular building (Figure 4) in Tehran oriented along an East-West axis. There are continuous ribbon windows along the North and South elevations from 4'-0" to 8'-0". The ceiling height as modeled is a standard 10'-0".

Figure 5. bulding section alonge north-south axis

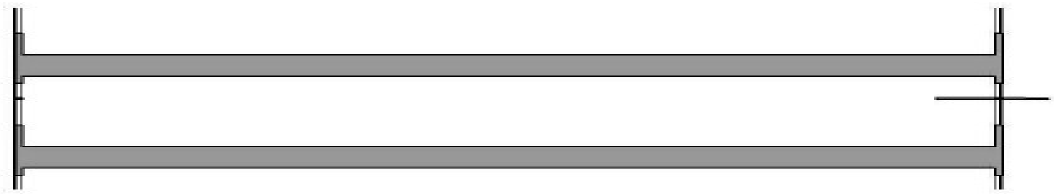


Figure 5 is a section of the building across the North-South axis. The North windows are unshaded. The South elevation has sunshades and light shelves as shown in Figure 3.

In this study the illumination levels at three different times on a typical summer day show that the daylight properties were set for June 21st, the longest day of the year. Calculations were done for 9am, 12noon, and 5pm to gather data on daylight levels throughout the day. The simulation shows that the recommended ambient light levels of 250 Lux were achieved across the entire floor plate during the middle of the day. In the morning and late afternoon, designed light levels were achieved within 15' of the South windows and 10' from the North windows. It does appear that light levels of 200 Lux were achieved across the entire floor from 9am to 5pm. There could be significant energy savings from lighting in the summer.
Also Daylight properties were set for September 21st (Equinox). In the middle of the day, the design light level was achieved with daylight alone. The South side of the building was able to achieve 200 Lux for most of the day. The North side had light levels below 200 Lux at the begining and end of the work day. It appears that there could be energy savings from lighting in the Fall and Spring as well. This simulation shows that the design could benefit from higher daylight windows and/or higher ceiling on the North side of the building.
Within 5' of South elevation, the illuminance level spiked up to 4400 Lux. There would be glare issues if workstations were place in this perimeter zone. At 9am, there were significantly high Lux levels on the South side of the building, indicated by the spikes on the graph. These numbers suggests direct sunlight falling on the

workplane. During the morning, interior blinds or shade cloths would likely be deployed; therefore, there would not be any useful daylight. There could be some energy savings from daylighting in the Winter, especially during the middle of the day; however, due to the shorter days and low sun angles, the savings would not be significant.

3. Results

Incorporating energy efficiency, renewable energy, and sustainable green design features into all Iran's buildings has become a top priority in recent years for facilities managers, designers, contracting officers, and others in government Buildings procurement.
The whole-building approach is easily worth the time and effort, as it can save 30% or more in energy costs over a conventional building designed in accordance with sustainable green design. Moreover, low-energy design does not necessarily have to result in increased construction costs. Indeed, one of the key approaches to low energy design is to invest in the building's form and enclosure (e.g., windows, walls) so that the heating, cooling, and lighting loads are reduced, and in turn, smaller, less costly heating, ventilating, and air conditioning systems are needed. In designing low-energy buildings, it is important to appreciate that the underlying purpose of the building is neither to save nor use energy. Rather, the building is there to serve the occupants and their activities. An understanding of building occupancy and activities can lead to building designs that not only save energy and reduce costs, but also improve occupant comfort and workplace performance. As such, low-energy building design is a vital component of sustainable, green design that also helps Iran manager's for attention the climate factors in buildings design.

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